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Density and size structure of the endangered fan mussel *Pinna nobilis* (Linnaeus 1758), in the shallow water zone of Maliakos Gulf, Greece

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A total of 346 live animals of the endangered species fan mussel Pinna nobilis *(Linnaeus 1758) were recorded in situ in the shallow water zone (<2m) within two sites of the marine protected area "Natura 2000" of Maliakos Gulf (Central Hellas). Our results showed that the recorded length (from 11.89 to 72.51 cm) of the fan mussels corresponds to ages that cover the majority of the species life time. Population densities were comparable to the higher values recorded previously in the Mediterranean Sea. The spatial distribution of species was clumped. Estimated total mortality was close to estimated natural mortality indicating that fishing activity does not significantly affect the population density and mortality of fan mussel in the study area. Population densities were related to sediment type, the buried length of animals was related to both sediment type and sea grass leaves size.*

Key words: Mediterranean, Maliakos Gulf, *Pinna nobilis,* fan mussel, population density, seagrass

INTRODUCTION

The fan mussel *Pinna nobilis* (Linnaeus 1758) is the largest endemic pteriomorphian bivalve in the Mediterranean Sea; specimens can grow up to 120 cm long (ZAVODNIK *et al.,* 1991). It is long lived (even up to 45-50 years) (RICHARDSON *et al*., 1999; KATSANEVAKIS, 2006; GALINOU-MITSOUDI *et al.,* 2006; ROUANET *et al.*, 2015); it occurs in coastal soft-bottom areas at depths between 0.5 and 60 m, mostly in seagrass meadows (ZAVODNIK *et al.,* 1991; RICHARDSON *et al*., 1999; GARCÍA-MARCH *et al.,* 2007a,b; COPPA *et al.,* 2010; 2013; PRADO *et al.,* 2014); but also in bare sandy bottoms (KATSANEVAKIS, 2006). *P. nobilis* live with around >35% of their length buried by the anterior portion of the shell which is attached by byssus threads to the substratum (SoHelFI 2007). Their shell have an isosceles triangle like shape and in the live animals it is buried in substrate by the vertex of the equal sides. The species plays an important ecological role, providing a new hard substrate to colonise, increasing the spatial heterogeneity for the surrounding soft bottom communities, and contributing to the overall increase of the local biotope complexity level (RABAOUI *et al*., 2009).

The species was well known for their therapeutic properties and was used medicinally during the Ancient Greek and the early Byzantine period (VOULTSIADOU *et al.,* 2010). In late 80's the global population of *P. nobilis* has been significantly reduced (VICENTE & MORETEAU, 1991; RUANET *et al*., 2015) as a result of recreational and commercial fishing for food, production of "sea silk" from byssus, use of its shell for decorative purposes, and incidental killing by trawling and anchoring (KATSANEVAKIS, 2006; ADDIS *et al.,* 2009; VOUTSIADOU *et al.,* 2009; KATSANEVAKIS *et al.,* 2011).

In agreement to article 3 of 92/43/EEC, the European ecological network "Natura 2000" for protected sites, was created, for the preservation of the natural heritage (http://www.natura.org/). *P. nobilis* has been listed in 92/43/EEC (Annex IV) and in Barcelona Convention UNEP (1996)-referred to the Protocol for Specially Protected Areas Biological Diversity (Annex II) as an endangered species in the Mediterranean and is under strict protection. Fruitful outcomes of these measures (that are incorporated into the national legislations of the most of the Mediterranean countries), are the recent indications of light recover of the *Pinna* populations, especially in Marine Protected Areas (TRIGOS *et al*., 2013; ROUANET *et al*., 2015).

The fan mussel is a well-studied organism (ZAVODNIK *et al.,* 1991; RICHARDSON *et al*., 1999; 2004; ŠILETIĆ *et al.,* 2003; GARCÍA-MARCH *et al.,* 2002; 2006; 2007a; 2007b; CENTODUCATI *et al.,* 2007; RABAOUI *et al*., 2007; 2008; 2009; 2010; ADDIS *et al.,* 2009; COPPA *et al*., 2010; 2013; DAVENPORT *et al*., 2011; NAJDEK *et al.,* 2013; TRIGOS *et al.,* 2014; 2015) on several aspects of its species biology and population ecology. However, relevant data from the eastern Mediterranean are only scarce (BASSO *et al*., 2015). The existing information focus on genetic and populational structure, spatially restricted in some localities of the north Aegean (GALINOU-MITSOUDI *et al.,* 2006; KATSARES *et al.,* 2008), within a small marine lake in the Korinthiakos Gulf (KATSANEVAKIS, 2006, 2007, 2016) in a closed bay on the north-west of Crete (KATSANEVAKIS & THESSALOU-LEGAKI, 2009), in the South-East Aegean (Dodecanese complex) (VAFIDIS *et al.,* 2014), in recruitment in Maliakos Gulf (THEODOROU *et al.,* 2015).

The present paper aims to assess the current status of fun mussel population in the environmental protected area "Natura 2000" Maliakos Gulf (Central Hellas) (site GR 2440002), by implementing non-destructive sampling techniques, in order to gather information on density and biometry. The study focused on the shallow water zone (up to 2 m) which expectedly the species receives the most important negative environmental and human impacts on their population dynamics (e.g. pollution, turbidity, intense hydrodynamic, fishing e.c.a.).

MATERIAL AND METHODS

Study area

Maliakos Gulf is located on the eastern side of mainland central Greece (38°51'39.82" N, 22°41'45.54" E) and part of the Aegean Sea (Fig 1); covering a surface of approximatively 100

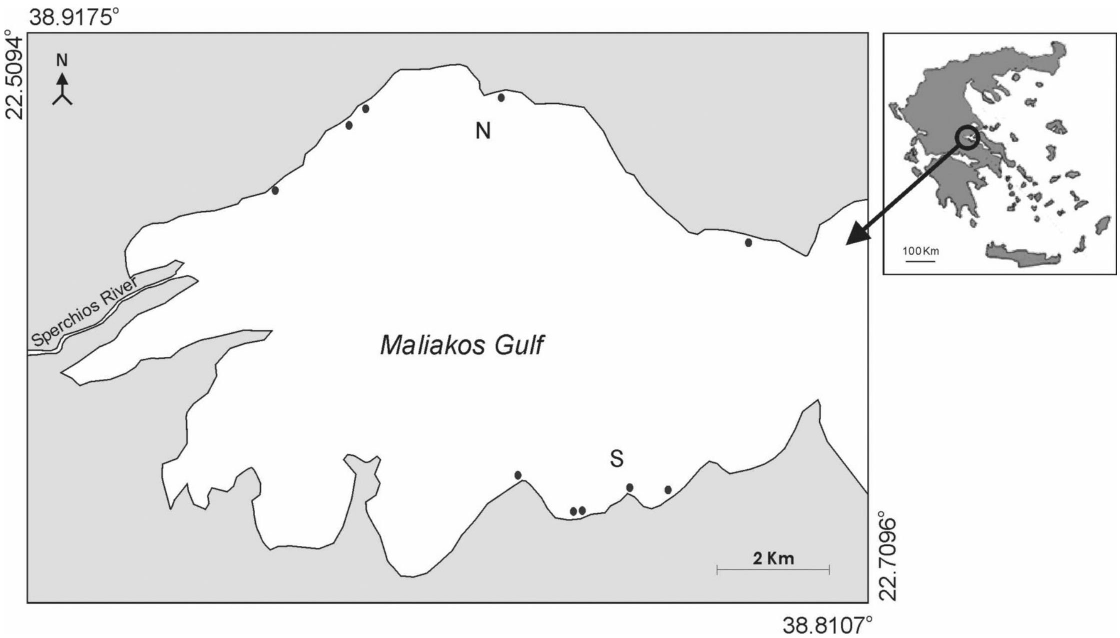

Fig.1. Map of the study area (Maliakos Gulf, East Central Hellas) with sampling stations (spots)

km^2 and connected with the north Evoikos Gulf by a channel ~2 km in width.

The gulf's depth varies from <2 m at it shallowest up to ~20 m; covering about 25% and 27% of the gulf's surface, respectively, while the rest and the major part of Maliakos (48%) is characterised by in between depths (2 to 20 m).

The tide in the area follows a semi-diurnal cycle with low amplitude (about 19 cm) (TSIMPLIS, 1994). The salinity ranged from 20 to 36 ppt and according to primary production and nutrients concentrations it is classified as an eutrophic marine ecosystem (DIMITRIOU *et al.,* 2015). The maximum wave height at the north part of gulf is ~1m while the average wave height ranged from 0.06 to 0.4 m (available data in: http://maliakos.stereahellas.gr/en/data/stationRecent/id/4). This area harbour an important aquaculture farming zone of the Mediterranean mussel *Mytillus galloprovincialis* (THEODOROU *et al.,* 2011; DIMITRIOU *et al.,* 2015) and there is also an important small scale fishing fleet (TZANATOS *et al.,* 2005).

Sampling

Samples were taken from the southern (S) and northern (N) part of the gulf between August - September 2009 at S and December 2011-January 2012 at N. It is clear that any difference on the following studied variables between the sites must be attributed on the interaction of site and year. Within each site, five stations, with an area of 100 m^2 (10x10m), were randomly selected at depths zone up to 2 m. In each station a SCUBA line transects technique was used (FEWSTER *et al.,* 2005; GARCIA-MARCH & VICENTE, 2006; KATSANEVAKIS, 2007); a line is stretched from one point to another and is followed, all organisms within the line, and a determined distance from the line on either side, are counted and data collected (Fig 2a). Once measured, organisms were marked by placing poles with bright markers on; this was done to stop multiple counts of the same animal.

In situ, at all recorded animals, the unburied length (UL), maximum width (W) and minimum width (w) were measured by a modified device of GARCIA-MARCH *et al.,* (2002). This device is a tree calliper with a measurement scale up to 370 mm width (between the opening prongs) and up to 310 mm length (down the prongs) respectively, to the nearest 1 mm (Fig. 2b). The total height of the fan shell (Ht) was determined using the equation: Ht = UL+h, where h is the buried length which is equal to 1.79w + 0.5 (GARCIA-MARCH *et al.*, 2002; MARCH & VICENTE, 2006).

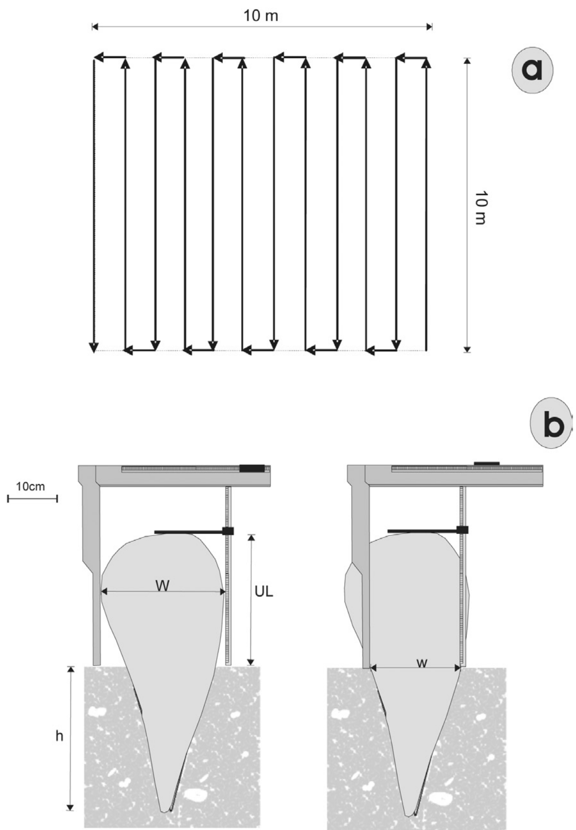

Fig. 2. Line transects on the area of 10x10m in each station (a), and (b) in situ measurements on unburied part of fan mussel (UL, W and w) and definition of burried length (h)

To determine the sediment type, three random samples from each, were taken. Sediment samples were taken using a corer to remove sediment down to 10 cm. Grain size analysis was applied on sediment samples in order to differentiate the sand (particles fraction that are greater than 63μm), silt (particles fraction that ranged from 2 to 63μm) and clay (particles fraction that are lower than 2 μm) components (FOLK, 1974; POULOS *et al*., 1996).

At each station a sample of 75 leaves of seagrass (consisting of species *Posidonia oceanica* and *Cymodocea nodosa*) were collected from five randomly chosen points of each station. Water depth at these points also has been taken into the account. Both, leaf length of and water depth were measured using a measuring-tape to the nearest mm.

Data analysis

Statistical differences in the morphometric characteristics of individual animals, density, sediment components, water depth and length of seagrass leaves with respect to sites were assessed by one-way analysis of variance by ranks (Kruskal–Wallis test; H-test, P=0.05) (Zar 1999). In this analysis the sediment components and the density were compared after applying arcsine root transformation and log-transformation on the raw data, respectively. In order to investigate the distribution type of species in each site the index cluster size determined as followed:

$$ICS = \frac{SD^2}{m} - 1$$

where SD and m are the standard deviation and average value of density, respectively. Under a random (Poisson) distribution *ICS* is expected to be equal to 0. Positive and negative *ICS* values indicate a clumped (aggregated) or a uniform distribution, respectively (DAVID & MOORE, 1954).

A simple regression analysis on the log-transformed data of the morphometric characters (ZAR, 1999) was used in order to characterize the relationships between them. The residuals of this analysis for the w and UL relationship (RSw(UL) is relieved from the effect on animal size and used in the following analysis. The variation of the RSw (UL) is a result of two factors: the morphological variation of shell and the burial length of shell. The latter attributed to the triangle shell shape and the way they bury in the substrate (Fig. 2b). Thus, for given Ht, increasing burial length, w is increased, UL decreased, while W remains constant. Thereafter, the increased quantities of RSw(UL) are related to burial shell length increase.

In order to examine any relationship amongst the dependent (density or RSw(UL)) and independent variables (mean depth, mean sediment components and the mean length of seagrass leaves of each station) multiple regression analysis (MR) was used. The independent variables used in the final MR model were selected through the stepwise variable selection

*Table 1. Mean value and standard deviation (in bracket) of UL: unburried length, W: Maximum width, w: minimum width, Ht: total length and density of fan mussel), and environmental variables (substrate composition: (sand, clay, silt), depth and seagrass leaf length (PoLi)) in two study sites: North (N) and South (S) Maliakos Gulf. ICS: Index of cluster size; *, ns: statistically significant and non-statistically significant difference between sites, respectively, (Kruskal–Wallis test;P=005)*

		Sites				
	Unit	N	S	P		
UL	cm	21.13 (4.92)	16.791 (7.80)	<0.001	*	(N>S)
W	cm	13.84 (25.02)	11.875 (3.86)	<0.001	*	(N>S)
w	cm	7.64 (2.36)	7.840 (2.97)	0.799	ns	(N=S)
Ht	cm	34.85 (7.53)	30.871 (12.11)	<0.001	*	(N>S)
Ht (Min-Max)	cm	11.00-57.50	12.00-72.50			
Sample size	number	249	97			
Density	Ind.$10^{-2}m^{-2}$	49.79 (43.61); ICS=37.91	19.09 (12.08); ICS=7.00	0.208	ns	(N=S)
Sample size	number	5	5			
Sand-part	%	80.95 (6.38)	82.27 (12.36)	0.294	ns	(N=S)
Clay-part	%	11.68 (3.83)	3.91 (3.99)	<0.001	*	(N>S)
Silt-part	%	7.996 (5.06)	13.76 (9.77)	0.041	*	(N<S)
Sample size	number	15	15			
Depth	cm	69.83 (24.61)	73.81 (32.44)	0.377	ns	(N=S)
Sample size	number	25	25			
PoLi	cm	17.93 (9.39)	39.07 (18.82)	<0.001	*	(N<S)
Sample size	number	375	375			

method and only the significant independent variables (P<0.05) were retained in the final MR model (ZAR, 1999). The explained variance of each dependent variable from an independent variable is an index of the importance of the independent variable to the dependent one (ZAR, 1999).

The Variance Inflation Factor (VIF) was used to evaluate the collinearity level amongst the explanatory variables (independent variables) on multi-regression analysis. High values of VIF mean a high level of collinearity. A common cut off threshold is VIF =10 (HAIR *et al*. 1998). So, variables with VIF >10 were exempted from multi-regression analysis. The above analyses were performed by SPSS ver. 17.0 statistical package.

Finally, in order to estimate the level of fan mussel fishing in the study area, the instantaneous fishing mortality (F) was estimated from the equation: F=Z-M, where M and Z are the instantaneous natural and total mortality, respectively. The Z and their confident limits (significant level 0.95: $CL_{95\%}Z$) were estimated by the Length-Converted Catch curve (FishSTAT II, ver. 1.2.2, FAO, Rome) for sets L_∞, k have been estimated for species from previous papers. M by the Pauly's empirical equation ($\log(M)=-0.0066-0.279\log(L_\infty)+0.6543\log(k)+0.4634\log(T)$) (FishSTAT II, ver. 1.2.2, FAO, Rome), was estimated, for mean temperature (T) of 18°C.

RESULTS

During the study, 346 animals were recorded in two sites (97 in S and 249 in N). The smallest animal was 11.89 cm in length and the largest one was 72.51 cm, (mean value 33.7±9.91 cm), respectively. The width ranged from 6.0 to 21.0 cm (mean value 13.2±2.93 cm) (Fig 3a) and it showed a strong linear relationship (R^2=0.73) with the total length of animals (Fig 3b). Also, statistically significant power relationships were shown on the unburied length and maximum width ($W=4.29UL^{0.65}$, R^2=0.73; N=346; P<0.001), the unburied length and mini-

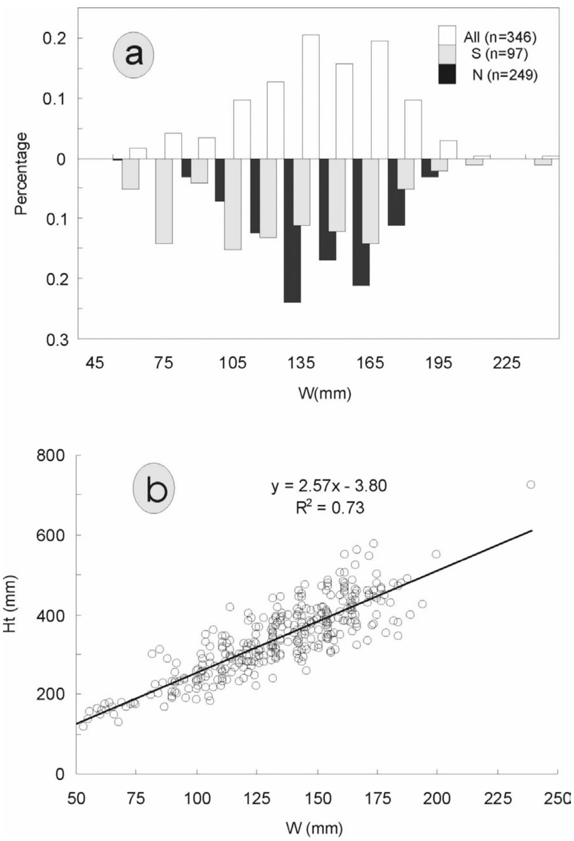

Fig. 3. Maximum shell width (W) distribution of fan mussel (a) of pooled samples (All) of South Maliakos (S) and North Maliakos (N) samples, n is the individuals number and (b) the relationship of Total shell length (Ht) to maximum width (W) of their shell

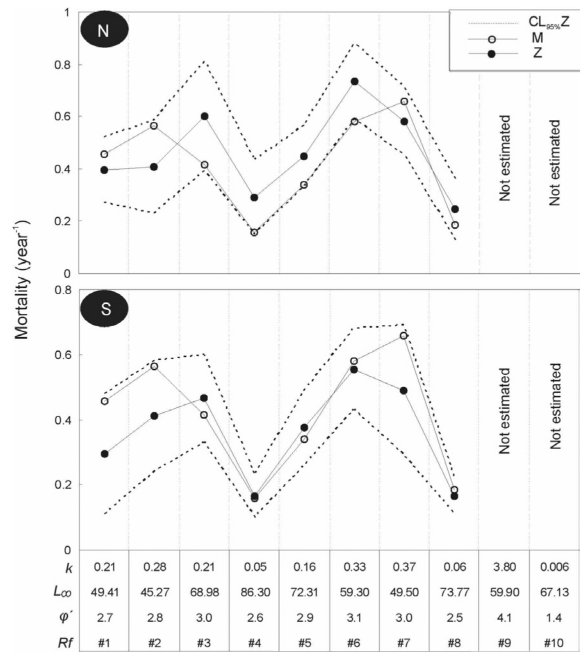

Fig. 4. Estimated M, Z and confident limits (significant level 0.95 of Z : CL95%Z) for fan mussel in Maliakos Gulf from the length distribution curve using data sets L∞, k from literature (Rf) cited in GALINOU-MITSOUDI et al., (2006): Rf#1,2,3:RICHARDSON et al., (1999), Rf#4: MORETEAU & VICENTE, (1982), Rf#5 :SILETIC & PEHARDA, (2003), Rf#6,7,9: RICHARDSON et al., (2004), Rf#8: GALINOU-MITSOUDI et al., (2006), Rf#10: GARCÍA-MARCH et al., (2002). φ' (=2Log(L∞)+Log(k)) is the index of the overall growth performance (PAULY & MUNRO, 1984). The sets L∞, k from Rf#9 and #10 are considered as outliers (φ':4.10 and 1.40, respectively, while the φ'of others ranged from 2.50 to 3.10)

mum width ($w=4.81UL^{0.51}$, $R^2=0.26$; N=346; $P<0.001$) and the maximum and minimum width ($w=1.069\ W^{0.86}$, $R^2=0.41$; N=346; $P<0.001$).

Total length, unburied length and maximum width of animals differed significantly between the sites. The density was 48.9±43.6 ind.$10^{-2}m^{-2}$ in the N and 19.1±12.1 ind.$10^{-2}m^{-2}$ in S, and observed densities did not significantly differ with respect to site. The ICS were 37.9 and 7.00 for N and S, respectively (Table 1).

The sand was the most common sediment particle at both sites (80.95±6.37% and 82.27±12.36% in N and S, respectively). The clay-part was estimated to be 11.68 ±3.83% in N and 3.91±3.98% in S while the silt-part was estimated to be 7.99 ±5.06% in N and 13.76±9.77% in S. From these, the clay and silt-part differed significantly between the sites (Table 1).

The depth ranged from 33 to 189 cm showed non-significant differences between the sites (mean depth 71.42 ± 27.26 cm). The length of seagrass leaves ranged from 7 to 69.9 cm and differed significantly between the sites (S: 39.07 ±19. 03 cm and N:17.93 ± 9.39 cm) (Table 1).

Figure 4 shows the estimated instantaneous (M) and total mortality (Z) from the length distribution curve of fan mussel in the study area. In both sites the estimated M was on the range of confident limits (95%) of Z estimation. This means that the M and Z did not differ significantly and thus the F did not differ significantly from 0.

The VIF for the variables mean- station parts of particles in sediment: sand, clay and silt, mean station length of sea grass leaves and mean

Table 2. Statistically significant coefficients (bi) of multi-regression model for the depended variables: density and residuals (RSw(UL)) of relationship w and UL and independent variables: mean station depth (depth), mean station seagrass leaves length (PoLi) and mean station sediment components (Silt-part and Clay-part). bi: Estimated coefficient, SS: sum of squared, %ExpVar: % explained variance, R2: coefficient of determination

	Density			RSw(UL)		
	bi	SS	%ExpVar	*bi*	SS	%ExpVar
Constant	3.07			-0.40		
Depth	0.45	6.30	2.80			
PoLi				0.26	5.63	17.80
Clay-part				-1.47	5.70	18.01
Silt-part	-4.96	64.50	28.90			
model SS		70.90			11.34	
Residuals		151.72			20.35	
total SS		222.62			31.69	
R^2		0.31	30.70		0.36	35.81

station depth, were 101.21, 2.01, 2.54, 6.65 and 5.01, respectively. Thus, the sand-part in sediment was exempted from the multiple regression analysis.

The results of the multiple regression analysis for the statistically significant independent variables are shown in Table 2. The mean depth and the clay–part in sediment in each station explained 30.70% of the total variance of the population density. The most explanatory variable was the silt-part in sediment (expVar%=28.90%) with positive link with the *Pinna* density.

The mean station length of seagrass leaves and the clay-part in sediment explained 17.80% and 18.01% of RSw(UL) total variance, respectively (total explained variance 35.81%). The length of the seagrass leaves showed positive link and the clay-part in sediment negative link by the RSw(UL), respectively (Table 2).

DISCUSSION

The total length of *Pinna nobilis* in the shallow zone of Maliakos gulf ranged from 11.89 to 72.51 cm. Combining von Bertallanffy parameter L_∞ from previous studies (RICHARDSON *et al.*, (1999; 2004); MORETEAU & VICENTE, (1982); SILETIC & PEHARDA, (2003); GALINOU-MITSOUDI *et al.*, (2006); GARCÍA-MARCH *et al.*, (2002)) (Fig 4) and the maximum observed length (L_{max}) (72.51 cm) in this study the ratio L_{max}/L_∞ could be thus estimated. The estimated L_{max}/L_∞ ranged from 0.78 to 1.28, indicate that the *P. nobilis* population in Maliakos gulf reached old ages. Nevertheless, the estimated age of the minimum observed length (11.89 cm) ranged from 0.95 to 16.00 years. However, observations on the recruitment and settlement of *P. nobilis* on ropes of a local Mediterranean mussel longline aquaculture, indicated that the animals shorter than to 19.00 cm (THEODOROU *et al.,* 2015) correspond to age up to one year.

The clumped distribution (ICS>7) appeared to be the common type spatial distribution for *P. nobilis* (GALINOU-MITSOUDI *et al.,* 2006; CENTODUCATI *et al.,* 2007; COPPA *et al.,* 2010; 2013). The densities of fan mussel in the present study area from 19 to 49.8 ind.10^{-2} m^{-2} are comparable to species densities estimated in South-East Spain 4-30 ind.10^{-2} m^{-2} (RICHARDSON *et al.,* 1999) and East Adriatic Sea 2-20 ind.10^{-2} m^{-2} (ŠILETIĆ & PEHARDA, 2003) which are significantly higher than in the other regions of Greek coastal water marine lake Vouliagmeni, Korinthiakos gulf: 4.7 ind. 10^{-2} m^{-2} (KATSANEVAKIS, 2006). Higher densities than the present study were reported in the Thermaikos Gulf which from 80 to 130 ind.$10^{-2}m^{-2}$ (MITSOUDI et *al.,* 2006).

The density variation among the regions could be attributed to various factors such as negative impact factors on density: fishing pressure and anchoring (KATSANEVAKIS, 2006; MITSOUDI *et al.,* 2006; CENTODUCATI *et al.,* 2007; KATSANEVAKIS, 2007; KATSANEVAKIS & THESSALOU-LEGAKI, 2009; HENDRIKS *et al.,* 2013; VAFIDIS *et al.,* 2014), the hydrodynamic stress (GARCIA-MARCH *et al.,* 2007a; KATSANEVAKIS & THESSALOU-LEGAKI, 2009) the pollution (CENTODUCATI *et al.,* 2007) and positive impact factor to density: trophic state (VAFIDIS *et al.,* 2014) of each region. Also, a depth-related size segregation of fan mussel was observed with the smaller individuals occurring more often in shallower waters and larger individuals being concentrated deeper (ZAVODNIK 1967; MORETEAU & VICENTE, 1982; VICENTE, 1990; VICENTE & MORETEAU, 1991; KATSANEVAKIS, 2006; GARCIA-MARCH *et al.,* 2007b; KATSANEVAKIS, 2007). The results observed in Maliakos Gulf indicated small effect of the depth on the density of species (Table 2), but this is expected due to the fact that sampling was done only to a maximum depth of 2 m. However, *P. nobilis* densities at this depth zone were about 10 to 35 times higher than the densities in other regions of the same zone (KATSANEVAKIS, 2006: 1.4 ind.$10^{-2}m^{-2}$; PRADO *et al.,* 2015: 0.5-2 ind.$10^{-2}m^{-2}$). This could be attributed to the low fishing pressure as well as to a possible low hydrodynamic (available data in: http://maliakos.stereahellas.gr/en/data/stationRecent/id/4) stress on animals (GARCIA-MARCH *et al.,* 2007; KATSANEVAKIS & THESSALOU-LEGAKI, 2009) and the high trophic state (VAFIDIS *et al.,* 2014) in the study area (DIMITRIOU *et al.,* 2015).

The fan mussel seems to favour meadows of the marine seagrass (*P. oceanica* and *C. nodosa*) (ZAVODNIK *et al.,* 1991), their distribution is affected by the availability of *P. oceanica* meadows (RICHARDSON *et al.,* 1999), and in several earlier studies the specimens were mostly located on the *P. oceanica* edge (COPPA *et al.*, 2010; 2013). COPPA *et al.*, (2013) stated that a higher efficiency in the filtering activity of *P. nobilis* on the meadow borders is related to a satisfactory hydrodynamic for efficient filtering activity, explaining the specimen aggregation on the edges (COPPA *et al.,* 2010; 2013). In contrast, within the meadow where the water flow is reduced by seagrass leaves (KOCH *et al.*, 2006; MANCA, 2010) the efficiency of filtering activity of animal could possibly be reduced. In the study area, although the relative position of animal in relation to meadows was not studied, the relatively low area of canopy that forms the seagrass meadow patches (personal observations), concomitantly to the low hydrodynamic ambient, seems to explain the fact that the length of seagrass leaves was not an important factor on the fan mussel density (Table 2).The negative link between *P. nobilis* density and silt-part (Table 2) was possibly related to the respiration efficiency and feeding activities of species. The excess of sediment loading may damage the cilia of *P. nobilis* reducing their respiration rate and feeding activities (THORSON, 1950; KATSANEVAKIS, 2006; GARCIA-MARCH *et al.,* 2008; COPPA *et al.*, 2010; 2013) and could have contributed to the high number of dead specimens and recruitment (COPPA *et al.*, 2010). However, the local low waving and current intensity seems to play an important role (KATSANEVAKIS, 2006) maybe via to the decreasing of substrate scraping.

In the present study a negative link RSw(UL) and clay-part in sediment was highlighted, indicating a decreasing trend in burial length in more clay sediments. This finding could be attributed to response to high fine sediment content as a compensatory response of the animal for avoiding detrimental effects on gills (COPPA *et al.,* 2010). On the other hand, the water flow within the meadow was reduced according to seagrass leaves (KOCH *et al.,* 2006; MANCA, 2010) and reduced the bottom upwelling leading to a reduction of the sediment in the water column. Furthermore, the vertical velocity of water within the meadow is higher in the lower part of plants, near the leaf sheath, than the upper one (KOCH *et al.*, 2006). Thus, in sites with seagrass with large leaves, the animals are able to exploit lower levels of water column, increasing the buried length, explaining the positive link of the RS w(UL) and length of seagrass leaves. However, this is not clear if is permanent or seasonal, because the data were collected in two sites during two seasons respectively and so, the results can be affected by the time-site interaction on leaves length as well as seagrass species-site and seagrass species-time interactions.

In conclusion, after examining population data of fan mussel in the shallow water zones of the northern and southern part of the Maliakos Gulf, it can be seen that the species population is not under pressure at the moment. The observed length composition (from 11.89 to 72.51 cm) of the fan mussels corresponds to ages that cover the majority of lifetime of species. The estimated total mortality was close to estimated natural mortality indicating that fishing activity does not greatly affect the population density and mortality of fan mussel in the sample areas. The population densities were related to sediment type and were comparable to the higher densities of species in the Mediterranean. Also, the relative buried length of species in the substrate seems related by the sediment type. In order to sustain this healthy population from detrimental outside influences, further research is required to be carried out on the fan mussel recruitment as well as the depth distribution pattern of the species.

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Gustoća naseljenosti i veličinska struktura ugrožene vrste školjkaša periske, *Pinna nobilis* (Linnaeus 1758), u plitkom dijelu zaljeva Maliakos, Grčka

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SAŽETAK

Ukupno 346 živih primjeraka ugrožene vrste školjkaša periske, *Pinna nobilis* (Linnaeus 1758), zabilježeno je *in situ* u plitkom moru (<2m) na dvije lokacije unutar morskog zaštićenog područja "Natura 2000" zaljeva Maliakos (središnja Grčka). Naši rezultati su pokazali da zabilježena duljina (od 11,89 do 72,51 cm) periski odgovara starosnoj dobi koja pokriva većinu životnog vijeka vrste. Gustoća naseljenosti bila je usporediva s većim vrijednostima zabilježenim u Sredozemnom moru. Prostorna raspodjela vrste bila je hrpičasta (grupna). Procjena ukupne smrtnosti bila je blizu procijenjene prirodne smrtnosti što ukazuje da ribolovna aktivnost ne utječe bitno na gustoću naseljenosti i smrtnost periske na istraživanom području. Dubina ukopavanja periske ovisila je o tipu sedimenta i visini (veličini) listića morske trave.

Ključne riječi: Sredozemlje, zaljev Maliakos, *Pinna nobilis,* periska, gustoća naseljenosti, morska cvjetnica